What is claimed is:

1   1.   A machine translation decoding method comprising:

2   receiving as input a text segment in a source language to be

3   translated into a target language;

4   generating an initial translation as a current target

5   language translation;

6   applying one or more modification operators to the current

7   target language translation to generate one or more modified

8   target language translations;

9   determining whether one or more of the modified target

10   language translations represents an improved translation in

11   comparison with the current target language translation;

12   setting a modified target language translation as the

13   current target language translation; and

14   repeating said applying, said determining and said setting

15   until occurrence of a termination condition.

1   2.   The method of claim 1 wherein the text segment

2   comprises a clause, a sentence, a paragraph or a treatise.

1   3.   The method of claim 1 wherein generating an initial

2   translation comprises generating a gloss.

1   4.   The method of claim 3 wherein the gloss is a word-for-

2 word gloss or a phrase-for-phrase gloss.

1   5.   The method of claim 1 wherein applying one or more

2 modification operators comprises changing in the current target

3 language translation the translation of one or two words.

1   6.   The method of claim 1 wherein applying one or more

2 modification operators comprises (i) changing in the current

3 target language translation a translation of a word and

4 concurrently (ii) inserting another word at a position that

5 yields an alignment of highest probability between the source

6 language text segment and the current target language

7 translation, the inserted other word having a high probability of

8 having a zero-value fertility.

1   7.   The method of claim 1 wherein applying one or more

2 modification operators comprises deleting from the current target

3 language translation a word having a zero-value fertility.

1   8.   The method of claim 1 wherein applying one or more

2 modification operators comprises modifying an alignment between

3 the source language text segment and the current target language

4 translation by swapping non-overlapping target language word

5 segments in the current target language translation.

1   9.   The method of claim 1 wherein applying one or more

2   modification operators comprises modifying an alignment between

3   the source language text segment and the current target language

4   translation by (i) eliminating a target language word from the

5   current target language translation and (ii) linking words in the

6   source language text segment.

1   10. The method of claim 1 wherein applying one or more

2   modification operators comprises applying two or more of the

3   following:

4   (i) changing in the current target language translation the

5   translation of one or two words;

6   (ii) changing in the current target language translation a

7   translation of a word and concurrently inserting another word at

8   a position that yields an alignment of highest probability

9   between the source language text segment and the current target

10 language translation, the inserted other word having a high

11 probability of having a zero-value fertility;

12   (iii) deleting from the current target language translation

13 a word having a zero-value fertility;

14   (iv) modifying an alignment between the source language text

15 segment and the current target language translation by swapping

16 non-overlapping target language word segments in the current

17 target language translation; and

18   (v)   modifying an alignment between the source language text

19   segment and the current target language translation by

20   eliminating a target language word from the current target

21   language translation and linking words in the source language

22   text segment.

1   11.   The method of claim 1 wherein determining whether one

2   or more of the modified target language translations represents

3   an improved translation in comparison with the current target

4   language translation comprises calculating a probability of

5   correctness for each of the modified target language

6   translations.

1   12.   The method of claim 1 wherein the termination condition

2   comprises a determination that a probability of correctness of a

3   modified target language translation is no greater than a

4   probability of correctness of the current target language

5   translation.

1   13.   The method of claim 1 wherein the termination condition

2   comprises a completion of a predetermined number of iterations.

1   14.   The method of claim 1 wherein the termination condition

2   comprises a lapse of a predetermined amount of time.

1   15.   A computer-implemented machine translation decoding

2   method comprising iteratively modifying a target language

3   translation of a source language text segment until an occurrence

4   of a termination condition.

1   16.   The method of claim 15 wherein the termination

2   condition comprises a determination that a probability of

3   correctness of a modified translation is no greater than a

4   probability of correctness of a previous translation.

1   17.   The method of claim 15 wherein the termination

2   condition comprises a completion of a predetermined number of

3   iterations.

1   18.   The method of claim 15 wherein the source language text

2   segment comprises a clause, a sentence, a paragraph, or a

3   treatise.

1   19.   The method of claim 15 wherein the method starts with

2   an approximate target language translation and iteratively

3   improves the translation with each successive iteration.

1   20.   The method of claim 19 wherein the approximate target

2   language translation comprises a gloss.

1 21. The method of claim 20 wherein the gloss comprises a

2 word-for-word gloss or a phrase-for-phrase gloss.

1 22. The method of claim 19 wherein the approximate target

2 language translation comprises a predetermined translation

3 selected from among a plurality of predetermined translations.

1 23. The method of claim 15 wherein the method implements a

2 greedy algorithm.

1 24. The method of claim 15 wherein iteratively modifying

2 the translation comprises incrementally improving the translation

3 with each iteration.

1 25. The method of claim 15 wherein iteratively modifying

2 the translation comprises performing at each iteration one or

3 more modification operations on the translation.

1 26. The method of claim 25 wherein the one or more

2 modification operations comprises one or more of the following

3 operations:

4 (i) changing one or two words in the translation;

5 (ii) changing a translation of a word and concurrently

6 inserting another word at a position that yields an alignment of

7 highest probability between the source language text segment and

8   the translation, the inserted other word having a high

9   probability of having a zero-value fertility;

10   (iii) deleting from the translation a word having a zero-

11   value fertility;

12   (iv) modifying an alignment between the source language text

13   segment and the translation by swapping non-overlapping target

14   language word segments in the translation; and

15   (v) modifying an alignment between the source language text

16   segment and the translation by eliminating a target language word

17   from the translation and linking words in the source language

18   text segment.

1   27. A machine translation decoder comprising:

2   a decoding engine comprising one or more modification

3   operators to be applied to a current target language translation

4   to generate one or more modified target language translations;

5   and

6   a process loop to iteratively modify the current target

7   language translation using the one or more modification

8   operators, the process loop terminating upon occurrence of a

9   termination condition.

1   28. The decoder of claim 27 wherein the process loop

2   controls the decoding engine to incrementally improve the current

3   target language translation with each iteration.

1   29. The decoder of claim 27 further comprising a module for

2   determining a probability of correctness for a translation.

1   30. The decoder of claim 29 wherein the module for

2   determining a probability of correctness for a translation

3   comprises a language model and a translation module.

1   31. The decoder of claim 29 wherein the process loop

2   terminates upon a determination that a probability of correctness

3   of a modified translation is no greater than a probability of

4   correctness of a previous translation.

1   32. The method of claim 27 wherein the process loop

2   terminates upon completion of a predetermined number of

3   iterations.

1   33. The decoder of claim 27 wherein the one or more

2   modification operators comprise one or more of the following:

3   (i) an operator to change in the current target language

4   translation the translation of one or two words;

5   (ii) an operator to change in the current target language

6   translation a translation of a word and to concurrently insert

7   another word at a position that yields an alignment of highest

8   probability between the source language text segment and the

9   current target language translation, the inserted other word

10   having a high probability of having a zero-value fertility;

11   (iii) an operator to delete from the current target language

12   translation a word having a zero-value fertility;

13   (iv) an operator to modify an alignment between the source

14   language text segment and the current target language translation

15   by swapping non-overlapping target language word segments in the

16   current target language translation; and

17   (v) an operator to modify an alignment between the source

18   language text segment and the current target language translation

19   by eliminating a target language word from the current target

20   language translation and linking words in the source language

21   text segment.

1   34. A computer-implemented tree generation method

2   comprising:

3   receiving as input a tree corresponding to a source language

4   text segment; and

5   applying one or more decision rules to the received input to

6   generate a tree corresponding to a target language text segment.

1   35.   The method of claim 34 wherein the one or more decision

2   rules comprise a sequence of decision rules.

1   36.   The method of claim 34 wherein the one or more decision

2   rules collectively represent a transfer function.

1   37.   The method of claim 34 further comprising automatically

2   determining the one or more decision rules based on a training

3   set.

1   38.   The method of claim 37 wherein the training set

2   comprises a plurality of input-output tree pairs and a mapping

3   between each of the input-output tree pairs.

1   39.   The method of claim 38 wherein the mapping between each

2   of the input-output tree pairs comprises a mapping between leaves

3   of the input tree and leaves of the paired output tree.

1   40.   The method of claim 39 wherein mappings between leaves

2   of input-output tree pairs can be one-to-one, one-to-many, many-

3   to-one, or many-to-many.

1   41.   The method of claim 38 wherein automatically

2   determining the one or more decision rules comprises determining

3 a sequence of operations that generates an output tree when

4 applied to the paired input tree.

1   42.   The method of claim 41 wherein determining a sequence

2 of operations comprises using a plurality of predefined

3 operations that collectively are sufficient to render any input

4 tree into the input tree's paired output tree.

1   43.   The method of claim 42 wherein the plurality of

2 predefined operations comprise one or more of the following:

3   a shift operation that transfers an elementary discourse

4 tree (edt) from an input list into a stack;

5   a reduce operation that pops two edts from a top of the

6 stack, combines the two popped edts into a new tree, and pushes

7 the new tree on the top of the stack;

8   a break operation that breaks an edt into a predetermined

9 number of units;

10   a create-next operation that creates a target language

11 discourse constituent that has no correspondent in the source

12 language tree;

13   a fuse operation that fuses an edt at the top of the stack

14 into the preceding edt;

15   a swap operation that swaps positions of edts in the input

16 list; and

71

17   an assignType operation that assigns one or more of the

18   following types to edts: Unit, MultiUnit, Sentence, Paragraph,

19   MultiParagraph, and Text.

1   44.   The method of claim 43 wherein the plurality of

2   predefined operations comprises a closed set including the shift

3   operation, the reduce operation, the break operation, the create-

4   next operation, the fuse operation, the swap operation and the

5   assignType operation.

1   45.   The method of claim 41 wherein determining a sequence

2   of operations results in a plurality of learning cases, one

3   learning case for each input-output tree pair.

1   46.   The method of claim 45 further comprising associating

2   one or more features with each of the plurality of learning cases

3   based on context.

1   47.   The method of claim 46 wherein the associated features

2   comprise one or more of the following: operational and discourse

3   features, correspondence-based features, and lexical features.

1   48.   The method of claim 45 further comprising applying a

2   learning program to the plurality of learning cases to generate

3   the one or more decision rules.

1   49.   The method of claim 48 wherein the learning program

2   comprises C4.5.

1   50.   The method of claim 34 wherein the source language text

2   segment comprises a clause, a sentence, a paragraph, or a

3   treatise.

1   51.   The method of claim 34 wherein the target language text

2   segment comprises a clause, a sentence, a paragraph, or a

3   treatise.

1   52.   The method of claim 34 wherein the source language text

2   segment and the target language text segment are different types

3   of text segments.

1   53.   The method of claim 34 wherein each of the source

2   language tree and the target language tree comprises a syntactic

3   tree.

1   54.   The method of claim 34 wherein each of the source

2   language tree and the target language tree comprises a discourse

3   tree.

1   55.   A computer-implemented tree generation module

2   comprising a predetermined set of decision rules that when

3   applied to a tree corresponding to a source language text segment

4   generate a tree corresponding to a target language text segment.

1   56. The module of claim 55 wherein the source language text

2   segment comprises a clause, a sentence, a paragraph, or a

3   treatise.

1   57. The module of claim 55 wherein the target language text

2   segment comprises a clause, a sentence, a paragraph, or a

3   treatise.

1   58. The module of claim 55 wherein the source language text

2   segment and the target language text segment are different types

3   of text segments.

1   59. The module of claim 55 wherein each of the source

2   language tree and the target language tree comprises a syntactic

3   tree.

1   60. The module of claim 55 wherein each of the source

2   language tree and the target language tree comprises a discourse

3   tree.

1   61. The module of claim 55 wherein the predetermined set of

2   decision rules defines a transfer function between source

3   language trees and target language trees.

1   62. A method of determining a transfer function between

2   trees of different types, the method comprising:

3   generating a training set comprising a plurality of tree

4   pairs and a mapping between each tree pair, each tree pair

5   comprises a source tree and a corresponding target tree;

6   generating a plurality of learning cases by determining, for

7   each tree pair, a sequence of operations that result in the

8   target tree when applied to the source tree; and

9   generating a plurality of decision rules by applying a

10   learning algorithm to the plurality of learning cases.

1   63. The method of claim 62 further comprising, prior to

2   generating the plurality of decision rules, associating one or

3   more features with each of the learning cases based on context.

1   64. A computer-implemented discourse-based machine

2   translation system comprising:

3   a discourse parser that parses the discourse structure of a

4   source language text segment and generates a source language

5   discourse tree for the text segment;

6   a discourse-structure transfer module that accepts the

7   source language discourse tree as input and generates as output a

8   target language discourse tree; and

9   a mapping module that maps the target language discourse

10   tree into a target text segment.

1   65.   The system of claim 64 wherein the discourse-structure

2   transfer module comprises a plurality of decision rules generated

3   from a training set of source language-target language tree

4   pairs.

5